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FISH OIL, AN EFFICIENT ADHESIVE IN ARSENATE-OF-LEAD SPRAYS

By Clifford E. Hood, *Assistant Entomologist, Gipsy Moth and Brown-tail Moth Investigations, Bureau of Entomology* [1]

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In recent years many experiments and tests have been made with various substances added to arsenate-of-lead and other spray mixtures to increase their adhesive and spreading qualities. Some of these substances were soap, glue, casein, molasses, gelatine, glucose, and flour.

Washburn (*10, p. 3, 14*) in 1891 recommended whale-oil soap as an adhesive for sprays of Paris green, and stated that it had given perfect satisfaction. Fernald (*2*) in 1894 recommended the addition of 2 quarts of glucose or molasses to each 150 gallons of arsenate of lead mixture, to cause the insecticide to adhere to the leaves. Sirrine (*7*) in 1895 and later used a resin-lime mixture as an adhesive for Paris green and Bordeaux mixture when applied to cabbage and cauliflower. Lowe (*5*) in 1896 stated that glue, used at the rate of 2 quarts to 45 gallons of green arsenite mixture, proved more satisfactory than glucose, used in the same proportion. Parker (*6*) in 1912 suggested the possibility of using flour paste as an adhesive for arsenicals. Lees (*4*) in 1913 and 1914 tried a number of substances as adhesives for preparations of lime used as cover washes for trees in late winter and early spring. Some of the substances used were glue and flour, also a mixture of whiting, starch, glue, and potassium dichromate. Berger (*1*) in 1917 reported good results with linseed oil as an adhesive for Bordeaux mixture. Stearns

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(*9, p. 9, 15*) in 1920 stated that he had found either calcium caseinate or sea-moss stock, prepared by boiling the moss in water, to increase the adhesiveness of certain insecticides. Smith (*8, p. 7*) in 1922 stated that the use of caseinate as a spreader in the codling moth spray and the dormant lime-sulphur spray, recommended by him for the control of orchard insects in Idaho, adds materially to their effectiveness. Headlee (*3, p. 294*) found in 1923 that casein, and also flour, retain more than twice as much lead arsenate as is retained when no adhesive is used.

In 1921 the writer began a series of experiments along this line, his effort being to find, if possible, some substance which, when added to spray mixtures, would cause them to spread and adhere more strongly to foliage sprayed with them, especially foliage of a glossy nature.

WHY AN ADHESIVE IS NEEDED

Spraying operations against the gipsy moth begin about May 1 in New Jersey, and much later in New England, and continue for four to six weeks. All of the material is applied with high-power sprayers, and many tons of arsenate of lead are used annually in the infested area. The areas to be sprayed are carefully planned out, the crews for each sprayer selected, the necessary material obtained, and the time required to cover these areas carefully determined in order that the spraying may be done promptly enough to be effective. There are many drawbacks, however, which more or less upset these plans, among them being bad weather, when no spraying can be done; at other times, when large areas are sprayed, frequent rains wash practically all of the poison from the foliage, and a second, and sometimes a third, spraying is necessary. In such cases the cost of spraying the area is doubled or tripled, and where large areas are concerned the expense is much greater. Further, to be effective the spray mixture used in gipsy moth work must be stronger than is ordinarily used against most leaf-feeding insects and, when applied to the foliage, should for maximum efficiency remain there during the entire larval season of the gipsy moth. From these facts it can be seen that a really good adhesive would economize materials and labor and save much valuable time.

PRELIMINARY EXPERIMENTS

IN 1921

In 1921, 1922, and 1923 the writer's experiments were conducted in a small way, with small hand sprayers, compressed-air sprayers, or an ordinary barrel pump equipped with two paddles at the bottom of the barrel for agitation. In 1921 a number of combinations were tried. The mixtures were sprayed upon glass plates and allowed to dry thoroughly, after which they were tested by rubbing lightly with the fingers and by placing them beneath a stream of lightly running water, striking with about the same force as would be encountered in a moderately heavy rainstorm. In one case linseed oil was the adhesive tested; in every other case two ingredients were combined to make the adhesive. Following are the results recorded, the specified quantities of the ingredients in each case being mixed with 100 gallons of water and 6¼ pounds of arsenate of lead:

INGREDIENTS AND QUANTITIES		RESULTS
Flour	6 pounds	Spread well; easily dislodged.
Plaster of Paris	3 pounds	
Flour	3 pounds	Do.
Glue	3 pounds	
Flour	3 pounds	Do.
Gelatine	3 pounds	
Casein	3 pounds	Spread well; better than those mentioned above.
Hydrated lime	3 pounds	
Molasses	3 quarts	Spread fairly well; easily dislodged.
Hydrated lime	3 pounds	
Molasses	1½ quarts	Spread fairly well; rather easily dislodged.
Hydrated lime	3 pounds	
Soap powder	3 pounds	Do.
Casein	3 pounds	
Plaster of Paris	6 pounds	Do.
Casein	6 pounds	
Hydrated lime	6 pounds	
Linseed oil	3 gallons.	Spread well; not easily dislodged.

In these tests it was found that the most promising materials for adhesives were casein, lime being added to bring it into solution, and linseed oil.

IN 1922

In 1922 both of these adhesives were given further tests, together with another which might prove of value. Woodland trees, such as birch, cherry, maple, and oak, were sprayed with these materials and examined frequently during the summer, the amount of spray washed off, if any, being noted. The rainfall during the summer of 1922 was excessive in the section where these experiments were conducted. From June 7 to September 20, when the last examination of the foliage was made, a total of 18.71 inches of rain had fallen. As in 1921, the quantity specified of the adhesive taken was in each case mixed with 100 gallons of water and 6¼ pounds of arsenate of lead. The ingredients and quantities taken for these tests were as follows:

Linseed oil	1 gallon.
Linseed oil	2 quarts.
Linseed oil	1 quart.
Casein (proprietary)	¾ pound.
Gum Arabic	Each ¾ pound.
Potassium dichromate	

The examination of the foliage on September 20 showed that the greater part of the spray in the plot treated with the largest proportion of linseed oil still remained on the foliage, but slightly less of the spray remained on the foliage in the other two plots on which linseed oil was used. In the plot on which casein was used only slight traces of the spray could be found on the foliage on September 20, whereas in that treated with gum arabic more spray could be seen than in the plot last mentioned but much less than in those treated with linseed oil.

IN 1923

As linseed oil proved the best adhesive of any tried in 1921 and 1922, it was decided in 1923 to try other vegetable oils and an animal oil, to find, if possible, one that would prove to be a good adhesive but much less expensive than linseed oil.

Vegetable oils are placed in three classes—drying, semidrying, and nondrying. Of these only the drying and semidrying oils were used, the drying oils being linseed oil, soy-bean oil, and Chinese wood oil, and the semidrying oils corn oil and cottonseed oil. Fish oil was the only animal oil used. Some of the properties of these oils and their drying qualities when applied as a thin film on any surface are here set forth.

Linseed oil is obtained from the seeds of the flax plant, *Linum usitatissimum*, a native of central Asia, but cultivated in many parts of the world for the fiber, which forms linen, or the seed, from which the oil is obtained. The seeds contain from 36 to 42 per cent of oil, which is obtained from them by expression or extraction. It is of a golden-yellow color, dries rapidly on exposure to the air, and adheres closely to the surface beneath.

Fish oil, sometimes known as mossbunker oil, pogy oil, or whitefish oil, is obtained principally from menhaden, a shadlike clupeoid fish of the genus Brevoortia, very abundant on the North Atlantic coast of the United States. Light-pressed fish oil is obtained by steaming the fish and subjecting it to gentle pressure; the cheaper grades are extracted from the residues. The oil is yellow to brown in color and dries readily on exposure to the air, but adheres somewhat less strongly than linseed oil to the surface beneath. The price is about 75 cents per gallon in barrel lots.

Corn oil, known also as maize oil, is obtained from the germ of corn, after it has been separated in the manufacture of starch, or from the residues of corn obtained in the fermentation of alcohol. The oil from the former source is pale to golden yellow; that from the latter, reddish brown. Corn oil dries readily on exposure to the air, but does not adhere so closely to the surface beneath as does linseed oil or fish oil. Its price is about $1 per gallon in barrel lots.

Soy-bean oil, sometimes known as soja oil or Chinese bean oil, is extracted from soybeans. It is pale yellow to brown and dries slowly on exposure to the air, forming a soft film. Its price is about $1.10 per gallon in barrel lots.

Chinese wood oil, known also as Tung oil, is imported from the Orient, is pale yellow to dark brown, and on exposure to the air dries more rapidly than linseed oil, but does not adhere strongly to the surface beneath. Its price is about $2.60 per gallon in barrel lots.

Cottonseed oil is obtained from the seeds of the cotton plant, is pale yellow, and dries slowly on exposure to the air, but does not adhere to the surface beneath quite so well as does corn oil. Its price is about $1.05 per gallon in barrel lots.

As a preliminary test of the adhesiveness of sprays of arsenate of lead, each containing one of the six oils which have just been described, it seemed best to spray them on glass plates and observe their behavior after drying. Standard arsenate-of-lead mixture was used, successive portions of which contained one-half of 1 per cent and one-fourth of 1 per cent of each of the oils, making 12 different mixtures, all successively sprayed on glass plates. A cylindrical sprayer of the compressed-air type was used, the material being agitated by an occasional shaking of the pump. All of the oils mix mechanically with the water and are distributed through it in very fine globules. It was found better to add the arsenate of lead before adding the oil; by doing so the latter remained for a longer time distributed through

the mixture, and undoubtedly the oil attached itself more or less to the particles of arsenate of lead.

It was observed that linseed oil mixes well with the mixture, spreads very well over the plate, and when dry adheres strongly to the glass. Fish oil mixes practically as well as the linseed oil and is nearly as adhesive. Corn oil mixes readily and spreads fairly well over the plate, but does not adhere so strongly as does linseed oil or fish oil. Soy-bean oil does not mix well with the spray solution; even after violent agitation of the mixture the oil rises quickly to the surface. It does not adhere strongly to the glass plate. Chinese wood oil mixes readily and spreads fairly well over the plate, but does not adhere to the surface nearly so well as linseed oil or fish oil. It dries more rapidly than any of the other oils used. Cottonseed oil mixes fairly well with the mixture and is next to corn oil in its adhesiveness.

In this experiment linseed, fish, and corn oils gave the most satisfactory results. The mixtures containing one-fourth of 1 per cent of oil proved practically as efficient as those containing twice that proportion.

In the summer of 1923 standard arsenate-of-lead mixtures, each containing one-fourth of 1 per cent of one of the oils previously mentioned, were sprayed upon foliage, and observations were made frequently during the season. On June 15 of that year a few woodland trees—oak, birch, maple, and hickory—were sprayed with the arsenate-of-lead mixture containing linseed oil, and some oak, birch, hickory, beech, and maple trees with the mixture containing fish oil. On July 12 a few birch, oak, cherry, hazel, and ash trees were sprayed with the arsenate-of-lead mixture containing corn oil. Each of these three sprays, when applied to the foliage, has about the same spreading qualities.

On September 30 the last examination of the sprayed foliage was made. From the time of the application of the linseed-oil and fish-oil sprays to this date 5.74 inches of rain had fallen, and 4.95 inches from the time of application of the corn-oil spray. It was found that very little of the linseed-oil and fish-oil mixtures had been washed off. More of the corn-oil mixture had left the foliage, in spite of the fact that the linseed-oil and fish-oil sprays were subjected to a greater amount of rainfall. It was evident that corn oil is not quite so efficient an adhesive as is linseed oil or fish oil.

In the course of this season a few experiments were conducted with other materials as spreaders and stickers; some of the substances used were auto soap, powdered glue, and a proprietary casein product. Soap was used at the rate of 2 pounds to 100 gallons of water, and the arsenate-of-lead mixture containing this material was sprayed June 11, 1923, on the foliage of oak, cherry, birch, hazel, and maple trees. This material caused the spray to spread entirely over the surface of the leaf, and in all the experiments made no other substance used could quite compare with soap as a spreader. After a total of 4.15 inches of rain had fallen since the application of the spray on June 11, the foliage was examined on July 31, 1923, and practically all of the material was found to have been washed from it; only a very small quantity of the poison could be seen. On September 30 hardly a trace of the spray could be found remaining.

As the results of the experiments with powdered glue and the proprietary casein product did not show much promise, no details

relating to them will be given. This season's results showed that linseed oil and fish oil were the most satisfactory of the three other adhesives, with linseed oil perhaps slightly the better of the two, but the difference was very slight. The price of linseed oil in barrel lots in April, 1923, was $1.17 per gallon; that of fish oil, 79 cents per gallon. As the difference in effectiveness between linseed oil and fish oil was so slight, and the difference in price was so great, it can be seen that fish oil was the best all-around adhesive used in the season of 1923.

EXPERIMENTS CONDUCTED ON A LARGE SCALE IN 1924

From 1921 to 1923, inclusive, all of the experiments with adhesives were conducted in a small way, small sprayers and very limited areas being used. In 1924 these experiments were conducted on a larger scale, with high-power sprayers (fig. 1). The adhesives tested were linseed oil, fish oil, corn oil, lead oleate, flour, a proprietary casein product, soap, and a proprietary miscible oil. Two large areas in Somerville, N. J., were used; one, on Watchung Ridge, containing about 34 acres of deciduous growth, including more than 25 different species, and the other in Dukes Park, containing 9 acres of solid blue spruce.

FIG. 1.—High-power sprayer in operation at Watchung Ridge, Somerville, N J., 1924

EXPERIMENTS WITH DECIDUOUS TREES IN NEW JERSEY

On Watchung Ridge 10 different plots, 7 of 4 acres each, and 3 of 2 acres each, were under observation. Figure 2 presents a diagram of this area, with the numbers of the several plots. On these, respectively, the following adhesives were tested on the plots referred to by the numbers: Plot 1, soap; plot 2, corn oil; 3, fish oil; 4, linseed oil; 5, proprietary casein product; 6, lead oleate; 7, flour; 8 and 9, proprietary miscible oil; 10, arsenate of lead, without added substance.

In the Dukes Park area 7 plots were selected, each containing $1^2/_9$ acres. The same adhesives were used here as in the Watchung Ridge plots, with the exception of the proprietary miscible oil. Another area of seven 1-acre plots, containing a mixed growth, was selected in Saugus, Mass., and in these plots the same adhesives were used as in the Watchung Ridge area, except the proprietary miscible oil and the soap. A small area was selected in Melrose Highlands, Mass., for experiments with the proprietary miscible oil.

The lead oleate, so called, was a combination in paste form of lead oleate and lead arsenate. As it contained in all but 13.53 per cent of arsenic oxide, 50 pounds of it was required to equal the poison strength of 25 pounds of ordinary powdered arsenate of lead, since the latter contains about twice the percentage of arsenic oxide.

The season of 1924 was an excellent one for testing the adhesive qualities of different substances, the rainfall on the plots in both New Jersey and Massachusetts being above normal. After the spraying was finished and the materials thoroughly dried, representative col-

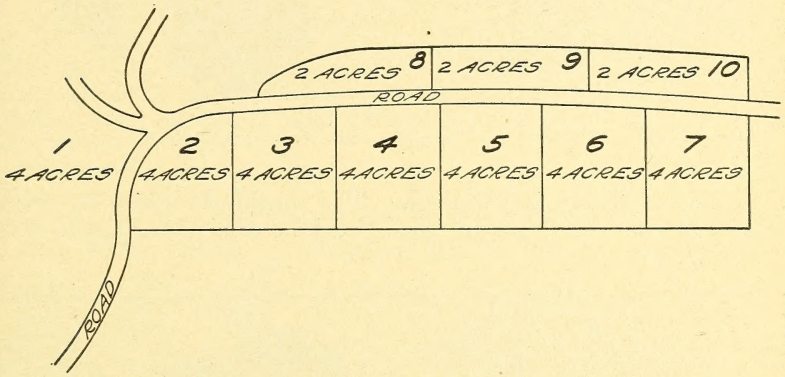

FIG. 2.—Diagram of plots at Watchung Ridge, Somerville, N. J., used in 1924 for tests of adhesives in arsenate-of-lead sprays

lections of the foliage were made from each of the plots. After each moderate or heavy rain another collection of foliage from each of the plots was made, care being taken to select samples which were not blotchy or oversprayed and which were located in the open where they would be subjected to the full force of the rain during the season. The amount of spray material washed off was estimated by comparing it with the foliage taken from the plot shortly after the poison was applied. The same method was continued throughout the season. Careful examinations of the foliage were also made to note if any injury had taken place. The following year plots were sprayed with arsenate of lead mixtures both with and without an adhesive, collections of the foliage were made at different periods during the season, and chemical examinations of the spray remaining on the foliage made. The results of these tests showed that they did not differ very materially from those made by comparison during the season of 1924.

The soap used in this series of tests was a semisolid sodium soap used in washing automobiles. It was mixed with a small quantity of water and added to the contents of the spray tank. Arsenate-of-lead mixtures containing this material spread well, entirely covering

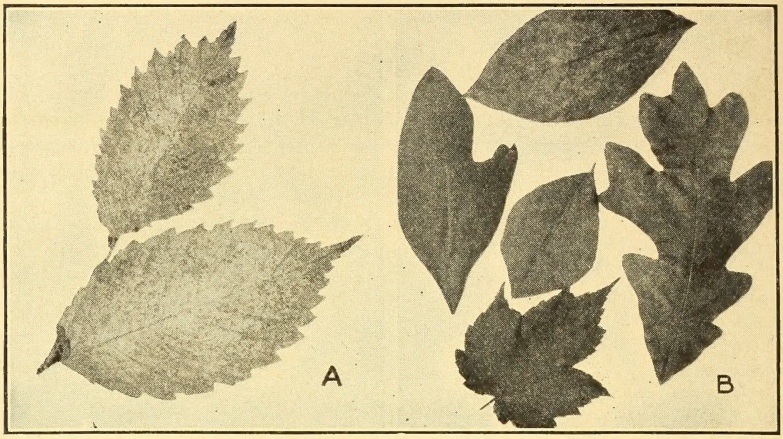

FIG. 3.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing soap as adhesive. A, foliage shortly after application of spray, June 4, 1924; B, foliage on September 17, 1924

the surface of all kinds of foliage. The spraying for testing this adhesive was done on a partly cloudy day at a temperature of 60° to 65° F. (fig. 3).

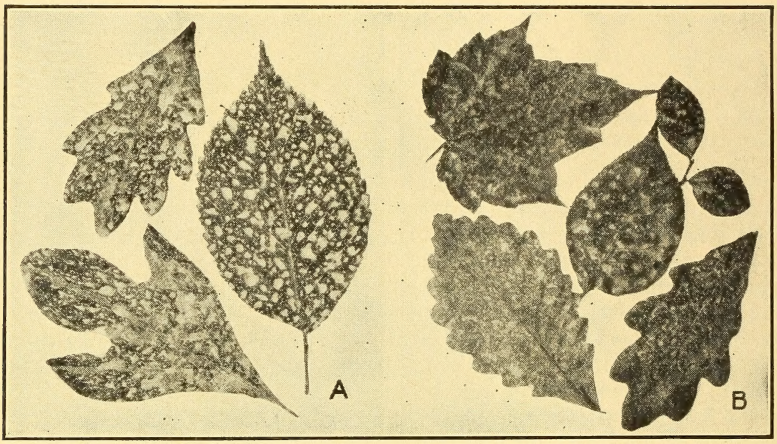

FIG. 4.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing corn oil as adhesive. A, foliage shortly after application of spray, June 4, 1924; B, foliage on September 17, 1924

The corn oil, owing to excellent agitation, mixed immediately with the arsenate-of-lead mixture. The spraying was done on a partly cloudy day with a light wind; the temperature was from 65° to 70° F. The spray spread fairly well over all kinds of foliage, but not so well as did the soap mixture (fig. 4).

The fish oil, when added to the arsenate-of-lead mixture, mixed almost instantly. It was sprayed on a partly cloudy day with light to moderate wind, at a temperature of 65° to 70° F. This material

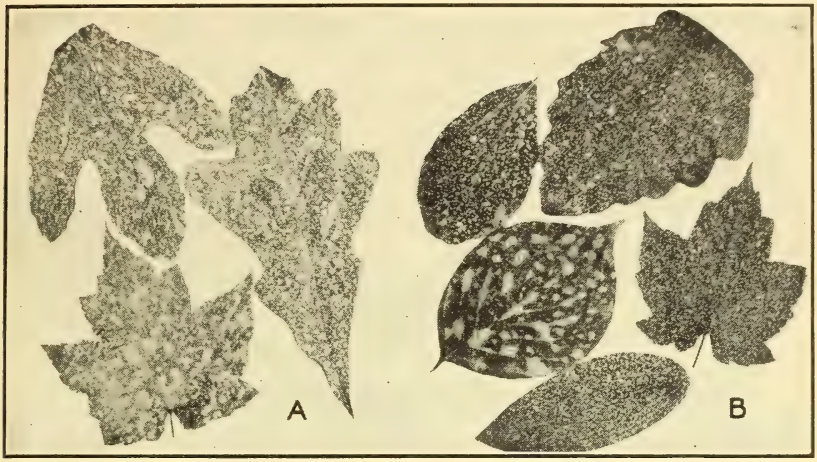

FIG. 5.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing fish oil as adhesive. A, foliage shortly after application of spray, June 5, 1924; B, foliage on September 17, 1924

spread over the foliage slightly better than the corn oil, but not so well as the soap (fig. 5).

The linseed oil mixed with the spray mixture as readily as did fish oil. The spraying was done on a partly cloudy day at a tempera-

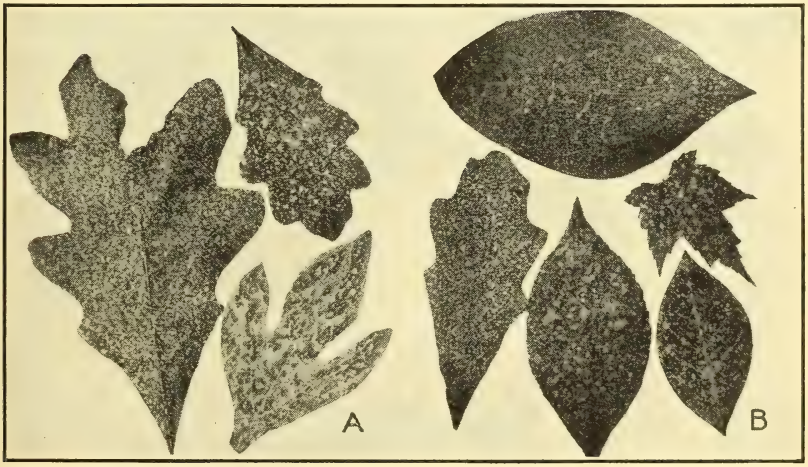

FIG. 6.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing linseed oil as adhesive. A, foliage shortly after application of spray, June 5, 1924; B, foliage on September 17, 1924

ture of 65° to 70° F. The spray spread fairly well, but did not cover the entire leaf, as did the soap mixture (fig. 6).

The proprietary casein product, a well-known article on the market, was mixed with a small quantity of water before being added to

the arsenate-of-lead mixture in the spray tank. The weather at the time of spraying was partly cloudy to cloudy and the temperature 65° F. This material spread well over the surface of the foliage sprayed except the new growth on white oak; as a spreader it was

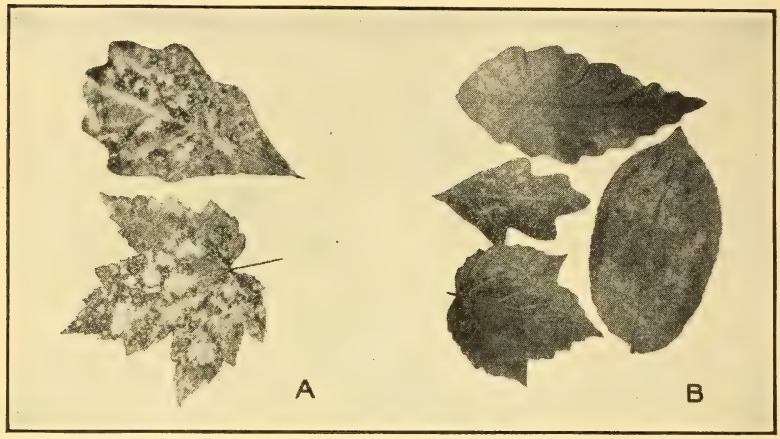

FIG. 7.—Appearance of foliage in plot at Watchung Ridge sprayed with mixture containing casein as adhesive. A, foliage shortly after application of spray, June 6, 1924; B, foliage on September 17, 1924

not so good as soap, but somewhat better than any of the other materials used (fig. 7).

The lead oleate, as has been stated, was a combination in paste form of lead oleate and lead arsenate; it was mixed with a small quan-

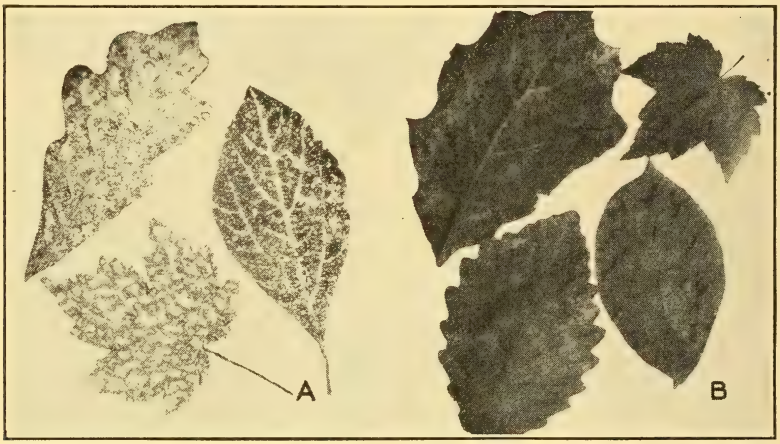

FIG. 8.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing lead oleate as adhesive. A, foliage shortly after application of spray, June 7, 1924; B, foliage on September 17, 1924

tity of water before being added to the mixture in the spray tank. The day of spraying was partly cloudy, with a temperature of 65° to 70° F. The liquid spread fairly well over the foliage, but was not quite so good in this respect as mixtures containing as adhesives the proprietary casein and the soap (fig. 8).

The flour used as one of the adhesives contained 16 per cent of gluten and was thoroughly mixed with the arsenate of lead before being brought into mixture in the spray tank. The day of the spraying was partly cloudy, with a temperature of 68° to 72° F.

FIG. 9.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing flour as adhesive. A, foliage shortly after application of spray, June 7, 1924; B, foliage on September 17, 1924

The mixture spread fairly well over some of the foliage, but not well over that of white oak. It was only slightly better, if any, than the arsenate of lead used alone (fig. 9).

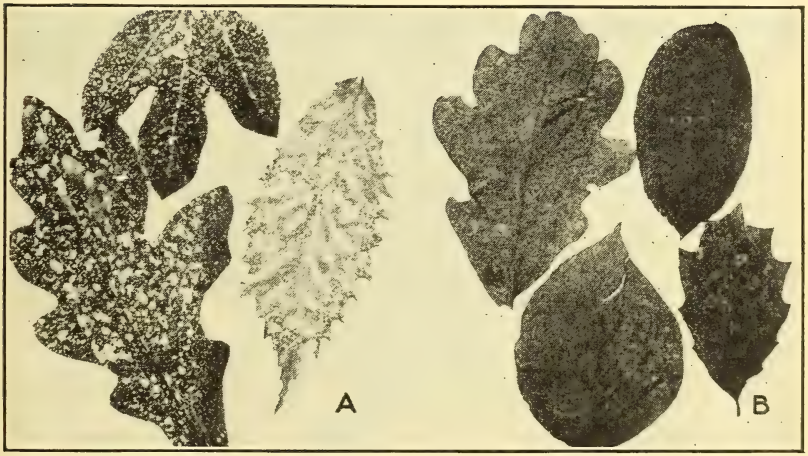

FIG. 10.—Appearance of foliage in plot at Watchung Ridge, sprayed with mixture containing proprietary miscible oil as adhesive. A, foliage shortly after application of spray, June 9, 1924; B, foliage on September 17, 1924

The proprietary miscible oil mixed readily with the arsenate-of-lead mixture. The day of spraying was partly cloudy; the spraying was done at a temperature of 70° F. Mixtures containing this material did not spread well over the foliage, especially that of the oaks (fig. 10).

Arsenate-of-lead mixture, without the addition of special adhesive, did not spread well over the foliage, especially the oaks, and very little, if any, would adhere to the new growth on white oaks. The spraying of this mixture was done on a partly cloudy day at a temperature of 70° F. (fig. 11).

EXPERIMENTS WITH CONIFEROUS TREES IN NEW JERSEY

As already stated, a 9-acre tract of solid blue spruce was chosen for testing the various adhesives when sprayed on the foliage of coniferous trees. The foliage on the blue spruce trees was very thick, and it was found necessary to use a spreader on the spraying nozzle, and to force the spray in between each tier of branches. Both the new foliage of the season and the older foliage were observed. The various adhesives were mixed with the arsenate-of-lead mixtures in the same manner as in the experiments with deciduous trees.

FIG. 11.—Appearance of foliage in plot at Watchung Ridge, sprayed with arsenate-of-lead mixture without the addition of special adhesive. A, foliage shortly after application of spray, June 9, 1924; B, foliage on September 17, 1924

The proprietary miscible oil, which had been tried in the experiments with deciduous trees, was not used with coniferous trees.

No special plot was laid out for experimenting with soap, as large areas of spruce throughout the park were being sprayed with arsenate-of-lead mixture containing it. In all cases the spray spread well over the old foliage but not so well over the new growth.

The fish oil spread well over the old foliage but not quite so well over the new growth. On the latter, however, it was just as good as soap, if not a trifle better. The mixture containing it was sprayed on a partly cloudy day with a light wind and a temperature ranging from 65° to 70° F.

The linseed oil spread well, about as did fish oil, over the old growth. The day of spraying was partly cloudy, with a light wind and a temperature of 68° to 72° F.

The corn oil did not spread so well over the foliage as did fish oil and linseed oil. When the spraying was done the weather was cloudy, with a temperature of 60° F.

The spray mixture containing lead oleate did not spread over the spruce foliage so well as fish oil or corn oil, and but little better than arsenate-of-lead mixture with no special adhesive. It was applied on a partly cloudy day, at a temperature of 70° F.

The spray mixture containing flour spread fairly well on the old growth when sprayed on spruce, but not so well on the new growth, being but slightly better than arsenate of lead alone. The spraying was done on a partly cloudy day, at a temperature of 70° F.

The proprietary casein product was found to spread very well over the old growth, but over the new growth not any better than the fish oil, if as well. It was sprayed on a clear day, at a temperature of 70° to 75° F.

The arsenate-of-lead mixture without special adhesive spreads fairly well over the old foliage, but will not spread over the new growth, and only a very little of the spray will remain on it.

For all the plots, except those on which the lead oleate was tested, 25 pounds of powdered arsenate of lead was used to 400 gallons of water, and to this mixture was added the quantity of adhesive recorded in Table 1. As the lead oleate was a combination of lead oleate and lead arsenate and was in paste form, containing only about one-half the percentage of arsenic oxide in powdered arsenate of lead, 50 pounds of this material was used to 400 gallons of water.

The spraying of the deciduous and coniferous foliage used for these experiments was begun June 4 and continued as rapidly as practicable on several dates, until on June 9 it was completed, as far as the trees at Watchung Ridge and Dukes Park were concerned. On June 14 an examination was made of the foliage which had been sprayed with the different mixtures, except the coniferous foliage sprayed with the mixture containing soap as the adhesive, and in the case of each one an estimate was made of the percentage remaining of the spray which had originally adhered. Between this date and that of the latest spraying all of the foliage had been subjected to rainfall of from 1¼ to 1½ inches. On June 26 a similar examination was made of foliage of several kinds, including that previously omitted; up to this time the rainfall since the last date of spraying had amounted to 3 inches. Similar examinations were made on July 9, August 11, September 17, and October 1, the total rainfall on the sprayed foliage at those dates being 5½ to 6, 9, 15½, and 19 inches, respectively. At least three, and in nearly all cases four, examinations were made for each spraying with a given adhesive. Table 1 gives various data relating to the adhesives used, their application, and the results of the several examinations of the foliage sprayed.

EXPERIMENTS WITH DECIDUOUS TREES IN MASSACHUSETTS

In order to compare the results of the tests made on the Somerville, N. J., plots, especially those of the Watchung Ridge area, with results of similar tests on plots located in New England, a mixed woodland was selected at Saugus, Mass. Seven plots, each containing about an acre, were sprayed, and the same adhesives were used with the arsenate of lead as were used in the Watchung Ridge area, with the exception of the proprietary miscible oil, which was tested in a small plot at Melrose Highlands, Mass. Deciduous growth only was used in Saugus and Melrose Highlands. The adhesives were added

TABLE 1.—*Data relating to tests of adhesives in arsenate-of-lead sprays at Somerville, N. J., in 1924*

Adhesive	Quantity of adhesive used with 25 pounds arsenate of lead and 400 gallons of water	Growth sprayed	Date of spraying	Temperature at time of application	Date of examination, days after spraying, and estimated percentage of spray remaining on foliage											
					First examination			Second examination			Third examination			Fourth examination		
					Date	Days	Per cent	Date	Days	Per cent	Date	Days	Per cent	Date	Days	Per cent
			1924	°F.	1924			1924			1924			1924		
Soap	8 pounds	Deciduous	June 4	60–65	June 14	10	20	July 9	35	15	Sept. 17	105	10			
		Coniferous	do		June 26	22	20	do	35	15	Oct. 1	119	10			
Corn oil	1 gallon	Deciduous	do	65–70	June 14	10	95	do	35	85	Aug. 11	68	80	Sept. 17	105	75
		Coniferous	June 6	60	do	8	90	June 26	20	85	July 9	33	75	Oct. 1	117	50
Fish oil	do	Deciduous	June 5	65–70	do	9	95	July 9	34	90	Aug. 11	67	85	Sept. 17	104	80
		Coniferous	do	65–70	do	9	95	June 26	21	90	July 9	34	85	Oct. 1	118	60
Linseed oil	do	Deciduous	do	65–70	do	9	95	July 9	34	90	Aug. 11	67	85	Sept. 17	104	80
		Coniferous	do	68–72	do	9	95	June 26	21	90	July 9	34	85	Oct. 1	118	70
Casein [1]	4 pounds	Deciduous	June 6	65	do	8	75	July 9	33	45	Aug. 11	66	35	Sept. 17	103	20
		Coniferous	June 9	70–75	do	5	90	June 26	17	55	July 9	30	40	Oct. 1	114	15
Lead oleate	50 pounds [2]	Deciduous	June 7	65–70	do	7	30	July 9	32	25	Aug 11	65	20	Sept. 17	102	15
		Coniferous	do	70	do	7	55	June 26	19	50	July 9	32	30	Oct. 1	116	15
Flour	6 pounds	Deciduous	do	68–72	do	7	50	July 9	32	25	Aug. 11	65	20	Sept. 17	102	15
		Coniferous	do	70	do	7	55	June 26	19	45	July 9	32	30	Oct. 1	116	15
Miscible oil [1]	4 gallons	Deciduous	June 9	70	do	5	60	July 9	30	50	Aug. 11	63	45	Sept. 17	100	40
None [3]		Deciduous	do	70	do	5	60	do	30	35	do	63	25	do	100	15
		Coniferous	do		do	5	55	June 26	17	45	July 9	30	25	Oct. 1	114	15

[1] Proprietary. [2] Includes the arsenate of lead. [3] Arsenate-of-lead mixture without special adhesive.

to the spray mixtures in the same proportions as were used in the experiments in Somerville. The spraying was done on June 12 and 13, except that for the miscible oil, which was done on June 24. The sprayed foliage was examined on June 26, July 22, August 5, and September 23, except that at Melrose Highlands, which was examined on the last two dates only. On these four dates the total rainfall after the dates of spraying was 1, 2½, 3, and 16½ inches, respectively. In Table 2 are presented various data relating to these tests, more particularly the estimated percentages which remained of the adhering spray. Here, as in the preceding tests, the drying oils are shown to be superior to the other adhesives used.

TABLE 2.—*Data relative to tests of adhesives in arsenate-of-lead sprays at Saugus and Melrose Highlands, Mass., in 1924, on deciduous growth*

Adhesive	Date of spraying	Date of examination, days after spraying, and estimated percentage of spray remaining on foliage							
		June 26		July 22		Aug. 5		Sept. 23	
		Days	Per cent	Days	Per cent	Days	Per cent	Days	Per cent
Lead oleate	June 12	14	55	10	30	54	25	103	15
Casein [1]	do	14	75	10	40	54	30	103	20
Corn oil	do	14	95	10	90	54	85	103	70
Flour	June 13	13	50	9	30	53	25	102	15
Fish oil	do	13	95	9	90	53	85	102	75
Linseed oil	do	13	95	9	90	53	90	102	80
None	do	13	45	9	30	53	25	102	15
Miscible oil [1]	June 24 [2]					42	65	91	40

[1] Proprietary. [2] Between June 12 and June 24 0.52 inch of rain fell

SUPERIOR ADHESIVENESS OF DRYING OILS

The value of any adhesive material is determined by the length of time that it will bind the spray to the foliage. Heavy rainfall or an excessive amount of fog or dew causes the poison gradually to disappear. Arsenate-of-lead sprays to which any of the three drying oils tested—i. e., fish oil, linseed oil, or corn oil—were added resisted throughout the season the washing action of the rain. The other materials tested were less satisfactory, as they failed to bind the poison firmly to the foliage. There was a tendency for the small particles of poison to become loosened and detached after having been exposed to considerable moisture, whereas the only observed effect of rainfall on the drying oils was a slight weathering of the poison on the sprayed surface. When growing foliage is treated a considerable loss of poison per unit area results, owing to the rapid increase in the leaf area, with no increase in the quantity of poison on the leaf. This is true regardless of the adhesive used, but more spray remains if one of the drying oils named is added to the arsenate of lead.

TESTS WITH A BARREL PUMP

On August 15, 1924, two small plots in a mixed woodland at Saugus, Mass., were sprayed with the standard arsenate-of-lead mixture to which was added one-fourth of 1 per cent of linseed oil for one plot and one-fourth of 1 per cent of fish oil for the other plot.

The pump used was of the ordinary barrel type, having two paddles at the bottom as an agitator. After the water and the arsenate of lead had been mixed in the barrel the oil was added and the whole agitated for five minutes. The mixture was allowed to stand for one hour. Most of the oil was taken up by the arsenate of lead, but a small quantity of free oil arose to the surface. The pump was then started and the spray applied. The material spread well over the foliage. The plots were examined on October 1, 47 days after the spraying, more than 10 inches of rain having fallen in the meantime. It was estimated that not over 15 per cent of the originally adhering material in the linseed-oil plot and 20 per cent of that in the fish-oil plot had been washed off, and no injury was noted on any of the foliage (fig. 12).

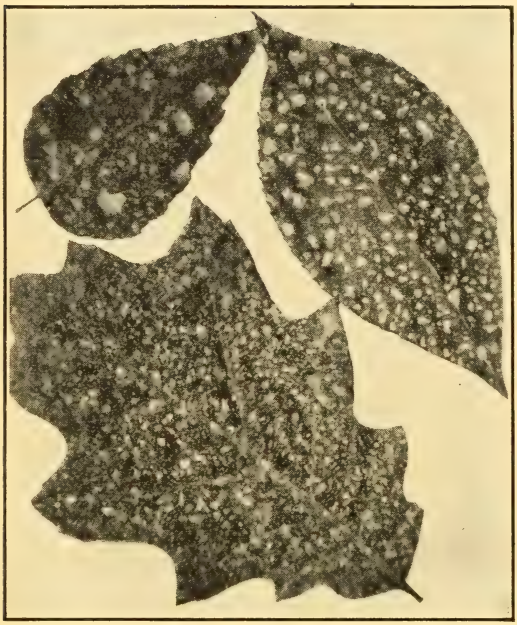

FIG. 12.—Appearance of foliage in plot at Saugus, Mass., 47 days after application of spray mixture containing fish oil as adhesive; the foliage had meanwhile been exposed to 10 inches of rainfall

ADHESIVES INJURIOUS TO FOLIAGE

LEAD OLEATE

As has been previously mentioned, lead oleate was applied at Saugus, Mass., June 12, 1924. On June 14 a light drizzling rain fell, lasting the entire day, but the precipitation was slight, the total being less than one-fourth inch. On June 18 the writer had occasion to visit the plots, and in going through that sprayed with lead oleate found that the foliage on the gray birches, the wild cherry, and some of the undergrowth was badly burned; some of the oak foliage was less severely burned. The foliage in the other six plots was carefully examined, but no signs of burning could be found on any of it.

On June 20 this plot was again examined, and burning was found on gray birch, red oak, black oak, and scrub oak, and on the undergrowth, such as blueberry, brake ferns, and false Solomon's seal (fig. 13). On June 26 more burning was noted in the plot, some of the oak trees being burned so badly that a large proportion of the foliage had withered and dropped to the ground. On July 22 more burning was noted. At this time it was estimated that 70 per cent of the spray had been washed off, and thereafter, until the end of the season, the injury did not seem to increase.

The lead-oleate plot located on Watchung Ridge, at Somerville, N. J., was sprayed on June 7, 1924. On June 14, when this plot was examined, no burning was noted, but this may be accounted for by the fact that on June 12 rain fell steadily for about four hours, and on June 13 a heavy rain lasted for about seven hours, and in these two days about 70 per cent of the lead oleate was washed off. Later in the season slight burning was observed in this plot, but in no case was it as bad as that in the plot at Saugus.

This lead oleate was furnished by the State of New Jersey. Later in the season it was found that the formula used at the factory where it was made was not satisfactory, and a change was introduced. The results here given cover the material used, and simply indicate that with this lot there was appreciable injury to the foliage.

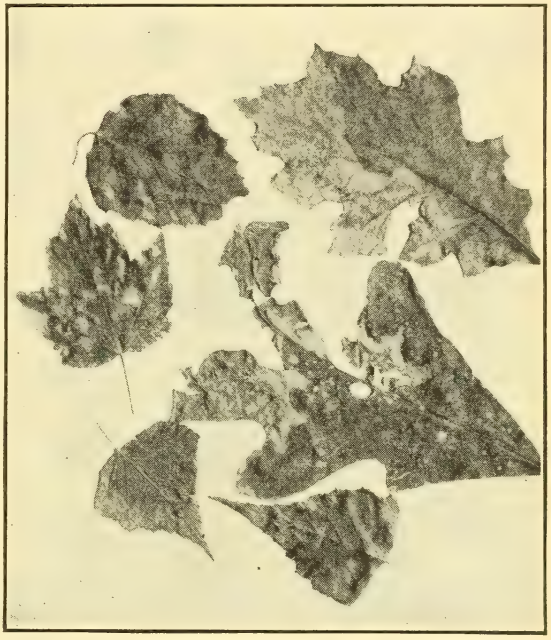

FIG. 13.—Foliage in plot at Saugus, Mass., burned by spray mixture of lead oleate

MISCIBLE OIL

For testing its possible injuriousness to foliage, the proprietary miscible oil was used in two dilutions; one the stronger, in the proportion of 1 gallon of the oil to 100 gallons of water, and the other in the proportion of 1 to 150. Two plots of foliage in the Watchung Ridge area were sprayed on June 9, 1924, each with one of these dilutions.

On July 9 the sprayed foliage on both plots was carefully examined, and on both some of it had suffered injury, the more extensive damage being found on the plot sprayed with the weaker mixture. Here the foliage on the maple, oak, ash, elm, and dogwood trees showed burning, some of it severe. In the other plot slight burning was noticed on some of the maple, oak, and dogwood foliage. The adhering spray seemed to have been washed away from the leaves here much more than from the foliage on the plot sprayed with the weaker mixture, which may account for the more severe injury to the latter. Slightly more burning in both of these plots was observed later in the season.

The proprietary miscible oil, diluted in the same two proportions as for the plots at Watchung Ridge, was similarly tested on two plots at Melrose Highlands, both of which were sprayed on June 24.

On June 26, two days later, in the plot sprayed with the stronger mixture, young, tender growth on red oak was found to be badly burned, and wild cherry foliage somewhat less so. On June 28 these injuries were more severe, especially in the case of the wild cherry, a number of leaves having suffered so badly that they had fallen off, and the fruit which had been touched by the spray had become discolored and injured. On July 2 many wild cherry leaves had fallen off and some of them had turned entirely black. Slightly more burning was noted from time to time for the rest of the season (fig. 14).

The foliage sprayed with the weaker mixture suffered less injury. On June 26 and 28 the wild cherry leaves were slightly burned, and much more severely on July 2. As in the case of the other plot, the injury progressed slightly during the season.

FIG. 14.—Foliage burned by proprietary miscible oil, diluted

CORN OIL

In the Watchung Ridge area at Somerville, N. J., slight burning was observed on dogwood foliage sprayed with the mixture containing corn oil, but no injury was noted on any of the other trees. Slight burning was noted on some of the foliage in the plot in the same area sprayed with the mixture containing no adhesive, so that the injury here may not have been due to the corn oil. No other injury was found in any of the other plots, either at Somerville or Saugus.

TESTS WITH RAW OILS

On August 7, 1924, to determine the effect of the direct application of raw oils to foliage, linseed oil, fish oil, and corn oil were sprayed separately in a raw state upon cherry, oak, and gray birch foliage on selected trees at Melrose Highlands. The trees were located at the edge of a woodland and in the direct sunlight. The spraying was done between 2.30 and 3 p. m., the temperature in the shade being 96° F. All of the oils spread over the entire surface of the foliage to which they were applied. The foliage was examined August 9 at 10 a. m., all being found in good condition. It appeared waxy, and

the oils were almost entirely dry (fig. 15). It was again examined August 13, but no burning by any of the oils was noted; on September 2 the foliage still appeared waxy, with no burning apparent. As a further test, on September 6 a few cherry, hazel, and gray birch trees were sprayed with crude (raw) fish oil, the cheapest grade obtainable. The foliage was examined September 11, no signs of burning being found; still later examinations showed no injury. It may be inferred from these experiments that foliage would not be injured if the oil added to the spray mixture should be applied unevenly to the trees.

SPRAYING NEAR BUILDINGS

In the control of the gipsy moth or other insects it is sometimes necessary to spray shade or fruit trees in close proximity to dwelling houses or other buildings. When this is done, even with the utmost

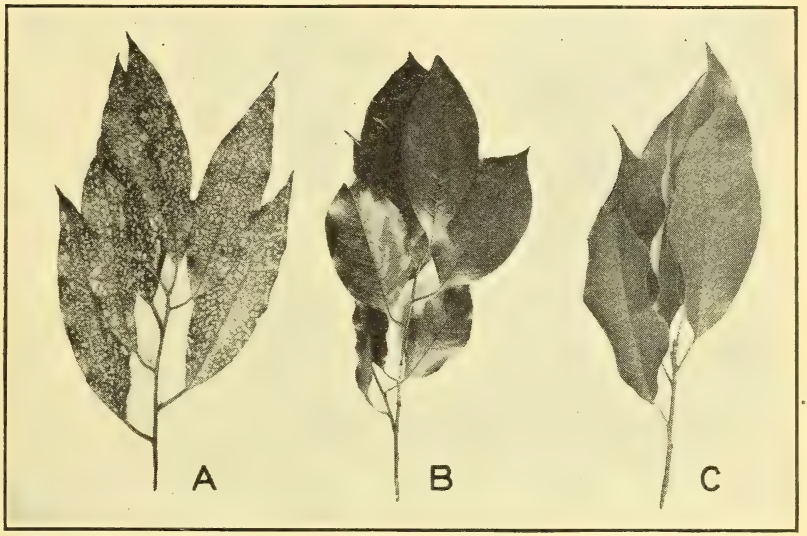

FIG. 15.—Appearance of leaves as affected by spraying: A, foliage sprayed with arsenate-of-lead mixture containing fish oil; B, foliage sprayed with raw fish oil; C, foliage not sprayed

care, some of the material may drift upon buildings, and if allowed to dry would render them unsightly. Spray mixtures containing fish oil as an adhesive can be readily washed from buildings if the latter are drenched with water before the spraying is begun and again sprayed with a garden hose after the spraying with the insecticide is finished. The final water treatment should be applied while the spray material is still moist. This operation should be performed promptly, as the oil dries rapidly after the evaporation of the water in the spray material.

CONCLUSION

As a result of the experiments and tests conducted in the seasons of 1921 to 1924, the materials which stand out preeminently as adhesives are linseed oil, fish oil, and corn oil, all three being drying oils, and for effectiveness they stand in the order named. Linseed oil

adheres more closely to the surface of the foliage than does the fish oil, but the difference is slight. Corn oil is not so good an adhesive as either of the other two, but is much more efficient than any of the remaining adhesives tried, which rank in the following order: Proprietary miscible oil, proprietary casein product, lead oleate, flour, and soap.

In view of the fact that fish oil is only slightly less efficient than linseed oil and is much less expensive, it is obvious that the former is the one to be recommended. In April, 1923, as previously remarked, the price of linseed oil was $1.17 per gallon, and that of fish oil 79 cents per gallon, in barrel lots; in March, 1925, the price of linseed oil was $1.23, and that of fish oil 75 cents per gallon; in May, 1926, the prices, in barrel lots, of linseed oil and fish oil were, respectively, 87½ cents and 70 cents per gallon. It is obvious how variable from year to year are the prices of such commodities. It can be readily seen that by the use of fish oil a great saving in the cost of spraying can be effected, especially when large quantities are used.

FIG. 16.—Undergrowth at Saugus, Mass., November 3, 1924, 144 days after it was sprayed with arsenate of-lead mixture containing corn oil as adhesive. The poison adhering is clearly shown. Livestock should not be allowed to eat vegetation so treated

Fish oil as an adhesive was used in arsenate-of-lead mixtures only. It was not used in combination with Bordeaux mixture (*1*), nicotine sulphate, soap, or any other ingredients. Further experiments should be conducted to determine the value of this oil when added to other spray mixtures.

In using fish oil as an adhesive one must bear in mind that the best results are obtained by adding the oil after the arsenate of lead has been well mixed with the water and while the mixture is being agitated. The mixture should be agitated at all times while it is being applied, not only to obtain an even coating of poison but to get maximum adhesiveness. In high-power spraying the agitation of the material is usually excellent, but in using the smaller outfits, such as the barrel pump, the agitation is sometimes poor, and satisfactory results can not be obtained either in the even distribution of the poison or in the adhesive qualities of the mixture.

The best grade of fish oil should always be used. This is known as "light pressed" and is yellow to brown in color. A cheaper grade

known as "crude fish oil" can be obtained, but as this contains stearin it is likely to clot, and it would not be economy to use it.

Fish oil can usually be obtained in all the larger cities, and linseed oil can be obtained in all cities or in towns of any size. In spraying operations where a 50-gallon barrel pump is to be used, and only a few barrels of the spray are to be applied, linseed oil could be resorted to, as only 1 pint of the oil is required to 50 gallons of the spray material. If a considerable amount of spraying is to be done, the use of fish oil greatly decreases the expense.

Large quantities of fish oil are used in gipsy-moth spraying operations. In purchasing it for this purpose the oil should be light pressed and unadulterated, and have the following specifications:

Saponification value	190 to 193
Iodine value	139 to 193
Specific gravity at 15° C	0. 927 to 0. 933
Free fatty acid	Less than 5 per cent.

The chief adulterant is mineral oil, the presence of which would be shown by a lowering of all of these characteristics.

Warning: Mixtures containing fish oil not only adhere strongly to the foliage on the trees but also to the undergrowth and vegetation beneath. Under no circumstances should livestock be allowed to graze during the season beneath trees that have been sprayed with such mixtures, as poisoning may result. Even in the late fall the spray appears so conspicuously on the vegetation beneath the trees that livestock may be poisoned by feeding upon it. Figure 16 shows a bit of undergrowth at Saugus, Mass., as it appeared on November 3, 1924, 144 days after being sprayed (June 12) with arsenate-of-lead mixture to which corn oil had been added as adhesive.

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